Reconstruction of auroral ionospheric conductivities via an assimilative technique and extension using COSMIC data

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McGranaghan et al. [2015a, 2015b, 2016, Submitted]

Key Findings

- First comprehensive principal component analysis using satellite particle precipitation data, yielding a new fundamental picture of ionospheric conductivity variability.
- New optimal interpolation technique reconstructs conductivities.
- Improved global conductivity distributions bring SuperDARN and AMPERE data into closer agreement, especially during geomagnetically active periods.
- Important COSMIC extension that improves understanding of data in high-latitude E Region ionosphere.

Introduction

We address a key barrier to system science for the magnetosphere-ionosphere coupling: (1) limited understanding of processes in the MIT system. We overcome these barriers with an observationally based, data assimilative technique for the MIT system. Specifically, we demonstrate the OI technique during the passage of a CME on November 30, 2011. We compare with the conductance models used therein - (a) Solar wind and geomagnetic activity data throughout November 30, 2011. Closer agreement between SuperDARN and AMPERE data when used in Assimilative Mapping of Ionospheric Electrodynamics (AMIE) procedure - (b) SuperDARN to predict AMPERE (δB) or (c) AMPERE to predict SuperDARN (δV).

Optimal Interpolation (OI) Technique

Reconstruction of complete high-latitude conductivities via optimal interpolation (OI) technique follows technique developed by Richmond and Kamide [1987] (AMIE), McGranaghan et al. [2009], and Cousins et al. [2013].

Objective: Optimally combine information from observations and a background model, taking into account error properties of both.

Background model: EOF-based mean (see next section) Observations: DMSP particle precipitation data

Error properties:
- For background model: Estimated from EOFs
- For DMSP particle precipitation data: Poisson statistics for observation error and EOFs

Conductances governed by a linear functional of background and observations: Aδx = Bx + D

Minimize squared error functional: Σ(x - x̄)TΣ(x - x̄) = ΣDΣD - 2ΣBΣ(x̄ - x̄)

Solve optimal interpolation: x̂ = B̂ = A-1D

The solution is a minimizer of squared error functional when

oi = 0 tox̄ = x̄

for any arbitrary constant vector tox̄. This means that the OI solution is the same as the background mean x̄ when the observation error covariance matrix ΣD ≈ 0.

Fundamental Picture of Ionospheric Conductivities: Empirical Orthogonal Functions

1. Directly-measured electron energy spectra from Defense Meteorological Satellite Program (DMSP) satellites F8-F9 and F16-F18 are used to characterize auroral ionization sources.
2. Global Airglow (GLOW) model [Solomon et al., 1998] is used to determine auroral electron temperature and density.
3. EOFs spread sparse information into global picture by deconstructing the Hall and Pedersen residual fields (νx) into a few dominant modes of variability (spatial fields in global picture). We demonstrate the OI technique during the passage of a CME on November 30 - 1

This is the same period analyzed by Cousins et al. [2015b] (hereafter C2015). We compare with the conductance models used therein - OI (hereafter M2015),: (a) Solar wind and geomagnetic activity data throughout November 30, 2011. Closer agreement between SuperDARN and AMPERE data when used in Assimilative Mapping of Ionospheric Electrodynamics (AMIE) procedure - (b) SuperDARN to predict AMPERE (δB) or (c) AMPERE to predict SuperDARN (δV).

Observations

Magnetic coordinate coverage by DMSP F6-F8, year: 1987 and F16-F18, year: 2011 (left) and northern hemisphere (right).

Otani et al. [2015a, 2015b, 2016] demonstrate the OI technique during the passage of a CME on November 30, 2011. We compare with the conductance models used therein - (a) Solar wind and geomagnetic activity data throughout November 30, 2011. Closer agreement between SuperDARN and AMPERE data when used in Assimilative Mapping of Ionospheric Electrodynamics (AMIE) procedure - (b) SuperDARN to predict AMPERE (δB) or (c) AMPERE to predict SuperDARN (δV).

Opportunities for further research:

- Develop OI technique for high-latitude E Region ionosphere
- Improve upper atmospheric data assimilation
- Conclusions: Critical data set to provide global coverage at high cadence Understanding in high-latitude E Region ionosphere limited Developing uncertainty model to enable COSMIC EDPs to be used to improve upper atmospheric data assimilation

References


Simplified model of ionospheric conductivities - Magnetic coordinate coverage by DMSP F6-F8, year: 1987 and F16-F18, year: 2011 (left) and northern hemisphere (right).

Magnetic coordinate coverage by DMSP F6-F8, year: 1987 and F16-F18, year: 2011 (left) and northern hemisphere (right).

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